REMARKS

1. Supplemental Amendments

The amendments herein corrects an informality in the previously presented amended claims 47, 49 and 60 to clarify that, for these claims, the number of system parameters is larger than a number of system equations. This subject matter included within Applicant's specification (see generally [0069] – [0180]), such as, but not limited to, [0065], [0163], [0182], and [0188]. In view of the present amendment, the previously submitted arguments directed to the 35 U.S.C. § 102(e) rejection are revised accordingly below and the remarks below are intended to replace those previously submitted wit respect to the 35 U.S.C. § 102(e) rejection.

2. The 35 U.S.C. § 102(e) Rejection of Claims 15-16, 47, 49, and 60

Claims 15-16, 47, 49 and 60 were rejected under 35 U.S.C. § 102(e) over Weiss (US 2003/0013541). Reconsideration and withdrawal of this rejection is respectfully requested in view of the amendments presented herein, which were acknowledged to overcome this rejection during the Examiner Interview.

As noted during the Examiner Interview, support for the amendments to the claims may be found, for example, in FIG. 1A and associated description in the specification, which shows a system 100 for detecting structural damage according to one embodiment of the invention. System 100 includes a stiffness parameter unit 103 configured to receive vibration information and provide natural frequency and/or mode shape data to detect the stiffness of a structure in question. As shown in FIG. 1A, stiffness parameter unit 103 may include an iterative processing unit 115 capable of determining stiffness parameters using a first order perturbation approach and the generalized inverse method. *See, e.g.*, par. [0065]. Stiffness parameter unit 103 may also or alternatively include an outer iterative processing unit 117 and an inner (nested) iterative

processing unit 119 which may operate using a first order perturbation approach and a gradient or quasi-Newton method. *See, e.g.*, par. [0065]. The gradient method is described, for example, in pars. [0138] to [0144] and [0150] to [0155]. The quasi-Newton method is described, for example, in pars. [0145] to [0155].

As to the recitations of the eigenvector sensitivity analysis or eigenvalue sensitivity analysis, Applicants disclose approaches to solving eigenvalues and eigenvectors of systems perturbed from a system with known eigenvectors and eigenvalues to determine the sensitivity of the eigenvalues and eigenvectors with respect to changes in the system (*see, e.g.*, pars. [0067], [0078], [0126], [0129]).

One example of such methodology begins with par. [0069] of Applicant's disclosure. In an N degree-of-freedom, linear, time-invariant, self-adjoint system with distinct eigenvalues, the stiffness parameters of the undamaged structure are denoted by G_{hi} (i = 1, 2, . . . , *m*), where *m* is the number of the stiffness parameters. The estimated stiffness parameters of the damaged structure before each iteration are denoted by G_i (i = 1, 2, . . . , *m*), and its stiffness matrix, which depends linearly on G_i, is denoted by K = K(G), where $G=[G_1, G_2, \ldots, G_m]^T$, where the superscript T denotes matrix transpose. The eigenvalue problem of the structure with stiffness parameters G_i is, as shown in Equation (1) ($K\Phi^k = \lambda^k M\Phi^k$) where M is the constant mass matrix, $\lambda^k = \lambda^k(G)$ and $\Phi^k = \Phi^k(G)$ (k=1, 2, . . . , N) are the k-th eigenvalue and mass-normalized eigenvector respectively. The eigenvalue problem of the damaged structure is $K\Phi_d^k = \lambda_d^k M\Phi_d^k$) where $K_d = K(G_d)$ is the stiffness matrix with $G(_d) = [G_{d1}, G_{d2}, \ldots G_{dm}]^T$ and $\lambda_d^k = \lambda^k(G_d)$ and $\Phi_d^k = \Phi^k(G_d)$ (see, e.g., par. [0072]-[0073]). The k-th eigenvalue and mass-normalized eigenvector of the damaged structure is related to λ^k and Φ^k through equation (5) (see par. [0075]-[0076]), wherein the first order sensitivity analysis for the difference between λ^k and λ_d^k

includes the summation, from $i = 1$ to m, the term $\lambda^{k}_{(1)i}\delta G_i$, where $\lambda^{k}_{(1)i}$ is the coefficient of the 1st order perturbation for the eigenvalue, and wherein the first order sensitivity analysis for the difference between Φ^k and $\Phi_d^{\ k}$ includes the summation, from $i = 1$ to m, the term $\mathbf{z}^{k}_{(1)i}\delta G_i$, where $\mathbf{z}^{k}_{(1)i}$ is the coefficient vector of the 1st order perturbation for the eigenvector.

Turning to the rejection of claims 15, 47, 49 and 60, the Examiner stated that Weiss disclosed, "a stiffness parameter unit (62) for receiving said vibration information (paragraph 0116, lines 1-3), determining natural frequency data or mode shape (vibration frequency, paragraph 0116, lines 4-5; paragraph 0016, lines 6-8) of said structure (paragraph 0116, lines 2-5), and determining the stiffness parameters of said structure using said natural frequency or mode shape data (paragraph 0116, lines 4-5; paragraph 0016, lines 6-8). The Examiner further stated that, with respect to claim 15, Weiss discloses a "damage information processor (61) for receiving said stiffness parameters and outputting damage information (data for non-perfect shaft vs. data for perfect shaft displayed via 257, paragraph 0159, lines 18-22, Fig. 25) comprising at least spatial damage information on said structure (spatial/asymmetry data, paragraph 0160, lines 2-3, represents spatial damage information). Weiss is said to teach "a damage extent processor (61) for determining extent of dame [*sic*: damage] information (257 shows deviations between data of non-perfect shaft and data of perfect shaft, Fig. 25)."

Weiss, par. [0116], states in its entirety the following:

> As shaft 110 oscillates, the motion of the shaft tip as sensed by tip mass and sensor assembly 1877 is recorded by processor 61, and in particular the maximum out-of-plane vertical acceleration or displacement and the vibration frequency are noted.

Weiss relates to the determination of a primary planar oscillation plane of a golf club shaft and discloses that the primary planar oscillation plane may be obtained by applying an impulse to the shaft and by measuring the oscillation of the shaft (see Abstract). Weiss

measures the out-of-plane oscillation at a large number of angular positions about the shaft axis, and the principal planar oscillation plane is identified by that pair of opposed angular positions in which the out-of-plane oscillation is smallest. *Id.* Once the location of the preferred orientation is found, it is marked on the golf club shaft so that the assembled golf club will have the planar oscillation plane in a predetermined orientation. *Id.*

In contrast, in accord with the present disclosure, Applicants provide a method and apparatus for detecting structural damage, and, more specifically, to a method and apparatus for detecting structural damage using changes in natural frequencies and/or mode shapes. *See*, par. [0003] of published patent application serial no. 20050072234 A1.

Illustrative examples of the disclosed concepts is described in the beam examples of pars. [0166] to [180] (see also FIGS. 7-11) and subsequent numerical and experimental verification scenarios (pars. [0184] to [0194]; FIGS. 12-17) and simulations (pars. [0195] to [0203]; FIGS. 18-21). In scenario 1, for example, a 45 cm long aluminum test specimen was divided into 40 elements, each element having a length of 1.125 cm, and was machined on top and bottom surfaces to simulate damage at a lengthwise position of about 10-15 cm, as measured from the cantilevered end (see par. [0187]; FIG. 13). The machining corresponded to 56% of damage (or reduction of bending stiffness EI) along the length of five elements (from the 9th to the 13th element). As shown in FIG. 13, results were obtained with 2-5 frequencies. As is noted by the Applicants in Applicant's specification, the extent of damage detected is slightly lower than the actual extent because the predicted damage occurs at 2 more elements (the 7th and 8th elements) than the actual one arising from the solution of the severely underdetermined system equations (5 equations with 80 unknowns).

As an additional illustration, FIG. 1B shows steps included in a method for detecting structural damage in accordance with aspects of the present concepts, including an initial step (1) measuring one or more eigenparameters, λ_d^k and Φ_d^k, which are then compared with estimated eigenparameters associated with the stiffness parameters, $G_i^{(0)}$ and the differences between the measured and estimated eigenparameters determined (2). These differences are then used in a sensitivity analysis to establish system equations (5) and (6) and an optimization method (e.g., gradient method, quasi-Newton method, etc.) is then used to find $G_i^{(w)}$ (see, e.g., par. [0134]-[0155]).

In contrast, Weiss (par. [0116]) is describing an oscillation of the tip of a golf club shaft 110 responsive to an impulse acting on the tip. The motion of the shaft tip is sensed by tip mass and sensor assembly 1877 and is recorded by processor 61. The maximum out-of-plane vertical displacement (or alternatively acceleration) is noted and the vibration frequency determined. Weiss discloses that the vibration frequency can be obtained by counting the number times in a given time interval that the vibrating shaft passes a fixed point (see par. [0056]). The Examiner also cites par. [0016], which states that "the vibratory motion of the golf club shaft is analyzed at a plurality of angular positions about the longitudinal axis of the shaft" and "[t]he greater the number of positions, the more accurately the planar oscillation plane--and particularly the principal planar oscillation plane--can be detected." As far as noting the maximum out-of-plane vertical displacement at a plurality of angular positions, FIG. 21 shows out-of-plane displacement plotted in polar coordinates as a function of angle (every 10°) wherein dashed lines 211 occur at the cusps between the lobes (local minima of out-of-plane displacement) and represent the planar oscillation planes (see also par. [0085]). Weiss discloses that, at each angular position, the vibration frequency of the shaft provides a measure of its stiffness. FIG. 25

shows a shaft frequency (CPM) vs. shaft angular position, showing square data points for the measured shaft.

FIG. 2 of Weiss shows the normalized horizontal and vertical displacement of the vibrating tip of shaft 10 as a function of time over two oscillation cycles, with horizontal displacement (x) represented by the solid line 20 and vertical displacement (y) represented by the broken line 21 (see also [0061]). FIG. 3 shows the same displacement of the tip of shaft 10 as a phase plot 30, over two cycles, in x and y. FIG. 4 shows the phase plot 40 after fourteen cycles. The phase plot 40 of the tip motion after a sufficient number of cycles is substantially a rectangle and the orientation of the planar oscillation plane is that of one of the two orthogonal axes of that rectangle, where each axis of a rectangle is defined as a line midway between, and parallel to, a respective pair of sides of the rectangle (see par. [0062]).

Claim 15 recites, *inter alia*, a sensor arranged to measure vibrations of a structure having a lengthwise dimension much greater in magnitude than cross-sectional dimensions thereof and to output vibration information, a stiffness parameter unit for receiving said vibration information, determining natural frequency data of said structure, and determining the stiffness parameters of said structure using said natural frequency data, and a damage information processor for receiving said stiffness parameters and outputting damage information comprising spatial damage information on said structure, "*said spatial damage information comprising a damage location along said lengthwise dimension of said structure*." Weiss does not disclose or suggest any methodology by which any alleged damage along a club shaft could be resolved to provide spatial damage information comprising a damage location along a lengthwise dimension of said structure.

Claim 47 recites a system for determining stiffness parameters of a structure, comprising a sensor arranged to measure vibrations of said structure and output vibration information, a stiffness parameter unit for receiving said vibration information, determining natural frequency data of said structure, and determining the stiffness parameters of said structure using said natural frequency data and wherein said stiffness parameter unit comprises an iterative processing unit that determines said stiffness parameters using a first order eigenvalue sensitivity analysis and one of the generalized inverse method, gradient method, or quasi-Newton method, wherein a number of system parameters is larger than a number of system equations. Weiss does not disclose or suggest each and every aspect of this claim and does not, for example, disclose or suggest a stiffness parameter unit comprising an iterative processing unit that determines stiffness parameters using a first order eigenvalue sensitivity analysis and one of the generalized inverse method, gradient method, or quasi-Newton method.

Claim 49 recites a system for determining stiffness parameters of a structure, comprising a sensor arranged to measure vibrations of said structure and output vibration information and a stiffness parameter unit for receiving said vibration information and determining said stiffness parameters with an iterative processing unit, wherein said stiffness parameter unit comprises an iterative processing unit that determines said stiffness parameters using a first order eigenvalue sensitivity analysis, wherein a number of system parameters is larger than a number of system equations. Claim 60 recites a system for determining stiffness parameters of a structure, comprising a sensor arranged to measure vibrations of said structure and output vibration information and a stiffness parameter unit for receiving said vibration information, determining mode shape information, and determining the stiffness parameters of said structure using said mode shape information, wherein said stiffness parameter unit comprises an iterative processing

unit that determines said stiffness parameters using a first order eigenvector sensitivity analysis, wherein a number of system parameters is larger than a number of system equations. Weiss does not disclose or suggest each and every aspect of claims 49 and 60 and does not, for example, disclose or suggest a first order eigenvalue sensitivity analysis or a first order eigenvector sensitivity analysis, let alone in the context claimed, instead resorting to the noted measurement of tip displacement (or acceleration) and frequencies.

The factual determination of lack of novelty under 35 U.S.C. §102 requires the identical disclosure in a single reference of each element of a claimed invention such that the identically claimed invention is placed into the recognized possession of one having ordinary skill in the art. *Helifix Ltd. v. Blok-Lok, Ltd*, 208 F.3d 1339 (Fed. Cir. 2000).

Weiss is respectfully submitted not to anticipate claims 15-16, 47, 49 and 60, which were rejected under 35 U.S.C. § 102(e). Withdrawal of this rejection is requested.

3. CONCLUSION

The Applicant respectfully submits that the claims are in a condition for allowance and action toward that end is earnestly solicited.

It is believed that no fees are presently due. However, should any fees be required (except for payment of the issue fee), the Commissioner is authorized to deduct the fees from the Nixon Peabody Deposit Account No. 50-4181 (266923-000007USPT).

Respectfully submitted,

July 29, 2008
Date

/William D. PEGG, Reg. # 42,988/
William Pegg
Registration No. 42,988
NIXON PEABODY LLP
161 North Clark Street, Suite 4800
Chicago, Illinois 60601
(312) 425-3900 - Telephone
(312) 425-3909 – Facsimile

ATTORNEY FOR APPLICANT